THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

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VOLUME 27 NUMBER 12

THE MOND NICKEL COMPANY LTD • SUNDERLAND HOUSE, CURZON STREET, LONDON, W.1
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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Metallurgical Reference Data for Engineers

AMER. SOC. MECHANICAL ENGINEERS: 'Metals Properties.' Edited by S. HOYT.
Sponsored by the Metal Engineering Handbook Board of The American Society of Mechanical Engineers.
Published by McGraw-Hill Publishing Co., Ltd., New York and London, 1954; 433 pp. and index.
Price $8·80.

The foreword states that 'this Handbook has been prepared to fill the urgent need for a reference manual related to the design engineer's point of view'. The *properties* about which the design engineer needs information have been tabulated and are presented in a form believed to be the most convenient for this type of user. (An earlier volume in the same series dealt primarily with the *design* function in metals engineering: a third, now in preparation, covers the *processes* by which metals and alloys are converted to finished products, and a fourth, also in preparation, comprises a *collection of engineering tables* which can supplement the engineer's knowledge of standards for shape, dimension, etc.)

The information presented is the result of correlation of contributions from many authentic sources; the American Society for Metals, which has already done so much in the field of reference literature, has co-operated in a specially active manner throughout the preparation of this volume.

The data are arranged in an essentially 'materials' classification; all information on one type of steel or non-ferrous alloy is given in one group, and, as far as possible, a uniform order is preserved for the presentation of the details relating to the individual materials. The properties recorded are for sizes, forms and conditions in which the materials are normally used or might be considered for use by the engineer. For the steels the various types are correlated with the appropriate A.S.T.M. specifications and A.I.S.I. gradings. In other cases, the user of this Handbook is directed to ascertain the requirements of current standard specifications, in order to check that the properties given in the Handbook coincide with those needed for specific applications.

The scope of the materials covered is as follows:—

Wrought and cast irons.
Cast steels.
Wrought steels.
Copper and copper-base alloys.
Aluminium and aluminium-base alloys.
Nickel and nickel-base alloys.
Zinc and zinc-base alloys.
Lead and lead-base alloys.
Magnesium and magnesium-base alloys.
Special alloys of heat- and corrosion-resisting types.

Non-Ferrous Metals: Extraction, Refining, Uses

W. H. DENNIS: 'Metallurgy of the Non-Ferrous Metals.' *Published by Sir Isaac Pitman and Sons, Ltd.*, London, 1954; 647 pp. Price 70/-.

This book is designed to give information of a comprehensive but condensed type, on the methods used for extraction and refining of the non-ferrous metals, together with notes on some of the main uses of the respective materials. It is based on (*a*) articles on the individual metals contributed by the author to various metallurgical and mining journals over a lengthy period, (*b*) information received from the many specialist organizations concerned with the individual metals, and (*c*) miscellaneous data culled from a wide variety of literature. A feature of the book is the number of drawings of flow sheets illustrating extraction and refining processes: due reference is made to the most recent modifications in the respective methods. At the end of the book a list is given of metallurgical plants to which reference is made in the text.

The chapter on *Nickel* includes description of the processes used for treatment of the nickel sulphide ores of the Sudbury region, Ontario; for the New Caledonian garnierite ore, and for the lower-grade ores found in Cuba. The electrolytic and carbonyl methods of extraction are considered, with illustrative flow sheets, and reference is made to the recent development of the pressure-leaching process now being applied for recovery of nickel from concentrates from the nickel-copper-cobalt-iron ores of the Lynn Lake Mine in Manitoba. In view of the character of the book, the sections on the properties and uses of nickel and its alloys are less detailed, but they give a bird's-eye view of the composition, properties and uses of the major materials in which nickel is an essential constituent.

See also abstract on p. 223.

Dimethyl-Glyoxime: Résumé of Information

'Dimethyl-Glyoxime.' *Laboratory Practice*, 1954, vol. 3, Oct., pp. 419-24.

This review is a communication from British Drug Houses, Ltd., Laboratory Chemicals Group.

It is pointed out that although dimethyl-glyoxime has been successfully used for many years for the detection and determination of nickel, it is only comparatively recently that other applications of the compound have been investigated. Information available from various sources is given under the following headings, each section being supported by references to the appropriate literature:—crystal forms, melting point, thermodynamic properties, optical properties,

spectrum, miscellaneous physical properties, chemical properties, reactions with metals and inorganic compounds, salts formed by dimethyl-glyoxime with nickel, cobalt, copper, palladium, rhodium, iridium, a gold dimethyl-glyoxime complex, reactions with organic compounds. Established and suggested uses for dimethyl-glyoxime are discussed, on the basis of the information summarized in the earlier part of the review and in the light of proposals recorded in the literature. The supporting *bibliography* contains 130 items.

Gas Evolution and Gas Permeability of Nickel and Other Metals

E. WALDSCHMIDT: 'Gas Evolution and Gas Permeability of Metallic Materials of Construction used in Vacuum Technique.' *Metall*, 1954, vol. 8, Oct., pp. 749–58.

Metallic materials are being increasingly used (in some cases replacing glass) as constructional materials for plant and apparatus employed in operations carried out in vacuo. The behaviour of such materials in relation to gases has therefore become highly significant.

This article comprises a commentary-review of factors relevant to such applications, including discussion of saturation pressure, physical and chemical adsorption, solubility and diffusion of gases in metals, gas-permeability and capillary gas-permeability. Supporting data in the various sections include values for iron, nickel, nickel-chromium, nickel-copper, and nickel-iron alloys, and various other metallic materials.

Preparation of Tensile Test Pieces by Photoengraving Technique

See abstract on p. 228.

Uses of Metals in the Automobile Industry

See abstract on p. 226.

NICKEL

Nickel Production at the Plants of the International Nickel Company of Canada, Ltd.

'International Nickel Company of Canada's Underground Mining Programme.'
'Underground Mining Practice at International Nickel's Sudbury Properties.'
'International Nickel's Mining Methods and Metallurgical Techniques.'
Mining Jnl., 1954, vol. 243, Oct. 29, Nov. 5 and 12, pp. 486–7; 514–17; 550–1.

A vast programme of underground development currently being prosecuted by The International Nickel Company of Canada, Ltd., at its mines in the Sudbury district of Ontario, is nearing completion. When the work is complete open-pit mining will be entirely replaced by underground production, and the changes made will substantially increase output of nickel.

In order not to interfere with the increasing demand for nickel during the years in which the development changes are in progress, and as a means of long-term improvement in production technique, extraction methods have been substantially modified and improved during the past few years.

The first of this series of three articles describes the geological formation of the ore deposits in the Sudbury region; the design of a typical underground nickel mine; and the Frood open pit, where, due to unexpected persistence of nickel-bearing ore, opencast mining will be continued until 1956.

The second article describes mining methods employed at the sites at which the Company is now operating underground: Frood-Stobie, Creighton, Murray, Levack, and Garson mines.

The final instalment gives some account of the stoping methods employed at the Inco mines, and discusses some of the improved mining and extraction methods which have been recently developed. Particular reference is made to a process for treatment of nickel-bearing pyrrhotite. The pilot-plant stage is now over and full-scale plant being constructed at Copper Cliff will recover nickel from low-grade pyrrhotite concentrates and at the same time produce high-grade iron ore. A further major development is the introduction of the new oxygen flash-smelting process, for treatment of copper concentrates. This procedure obviates consumption of fuel normally required for smelting, and makes economical large-scale output, by Canadian Industries, Ltd., of liquid sulphur dioxide from furnace exhaust gases. The operations call for a volume of more than 7,500,000 cu. ft. of oxygen per day.

As an indication of the increased output of nickel which has been achieved, by these and other methods resulting from intensive research and development, the following figures are given:—

At the end of 1953 Inco's nickel-producing capacity was at a rate of more than 275,000,000 lb. per annum, as compared with about 250,000,000 lb. at the close of the previous year. If demand continues to expand, the Company's scheduled production will permit delivery of approximately 1,380,000,000 lb. of nickel over the five-year period ending with 1958. These figures represent an increase of 325,000,000 lb. over deliveries for the five years 1945–1949.

Non-Ferrous Metals: Extraction, Refining, Uses

See abstract on p. 222.

Metallurgical Reference Data for Engineers

See abstract on p. 222.

Electron Micrographs of Fine Nickel Particles

'Electron Micrographs of Microstructure of Fine Nickel Particles.' *Bull. Amer. Soc. Testing Materials*, 1954, No. 201, Oct., p. 9.

Series of four micrographs illustrating core structure and crystallographic orientations within particles.

Relation between Elastic Modulus and Plastic Properties of Nickel

S. F. PUGH: 'Relations between the Elastic Moduli and the Plastic Properties of Polycrystalline Pure Metals.' *Philosophical Magazine*, 1954, 7th Ser., vol. 45, Aug., pp. 823–30.

Relations between the elastic and plastic properties of pure crystalline metals of many types are discussed, and a systematic relation between shear modulus, Burgers vector and plastic shear strength of metals possessing any given lattice structure is proposed. In addition, reasons are given for believing that, in a limited temperature range, malleability is related to Poisson's ratio. Nickel is among the metals from which data are presented in support of the conclusions reached.

Optical Characteristics of Nickel at Elevated Temperatures

G. GRASZ: 'The Optical Behaviour of Metals at High Temperatures.' *Zeitsch. f. Metallkunde*, 1954, vol. 45, Sept., pp. 538–47.

Report of investigations on iron, nickel, cobalt, manganese, copper, and silver. The author's results are correlated with those of other investigators. For the first five of these metals temperature (over the range 20°–1200°C.) is substantially without influence on emissivity in the visible spectrum.

Gas Evolution and Gas Permeability of Nickel and Other Metals

See abstract on p. 223.

Dimethyl-Glyoxime: Use in Determination of Nickel

See abstract on p. 222.

Chlorination of Nickel and Other Metals

R. C. OSTHOFF and R. C. WEST: 'The Chlorination of Metals in the Presence of a Donor Solvent.' *Jnl. Amer. Chemical Soc.*, 1954, vol. 76, Sept. 20, pp. 4732–4.

Pure anhydrous chlorides of metals are usually prepared by passing chlorine gas over the pure metals at elevated temperatures, since the procedure of drying the hydrated chlorides ordinarily leads to a certain amount of hydrolysis and loss of chlorine. This procedure is, in certain cases, unsatisfactory, for reasons briefly discussed by the authors. Other methods of preparation which have been suggested are reviewed, and an account is given of experimental work resulting in development of a technique for low-temperature chlorination of cobalt, nickel, manganese, zinc, and chromium, in several donor solvents. Chlorination of metals in the presence of suitable donor solvents appears to be a somewhat general reaction, although it was observed that none took place with tungsten, molybdenum, or silicon in the presence of ether. No reaction occurred if a non-polar solvent such as benzene was substituted for oxygenated solvents. It is therefore to be anticipated that the rôle of the solvent is to co-ordinate with the metal chloride and keep removing the chloride from the surface of the metal. Equations representing these reactions are proposed.

ELECTRODEPOSITION AND OTHER COATING METHODS

Electrodeposition of Coatings on Oxide-Soiled Surfaces

H. B. LINFORD and D. O. FEDER: 'Equipment for the Study of Electrodeposition on Oxide-Soiled Surfaces.' *Plating*, 1954, vol. 41, Oct., pp. 1183–7.
Report issued under the aegis of A.E.S. Research Project No. 12.

A metal which is to be electroplated frequently enters the plating bath with some inorganic contaminants, especially oxide, on its surface. Since this oxide often causes sub-standard coatings, research under this Project has been concerned with the study of the effects of electroplating onto metal surfaces so contaminated. In particular, attention has been directed to the mechanism by which plating on oxide-soiled cathodes takes place, taking into consideration four possible alternatives: (1) that the oxide is reduced, chemically or electrochemically, during the plating process, (2) that the oxide is covered by the coating metal and remains intact under the plating, (3) that the oxide is dissolved by the plating bath, or (4) that it is mechanically displaced during the plating operation.

The present report gives a well illustrated description of the construction and operation of equipment devised for studying the mechanism of deposition on soiled surfaces.

Influence of Cathode Rotation and Magnetic Fields on Structure of Electrodeposited Metals

L. YANG: 'Effect of Rapid Cathode Rotation and Magnetic Fields on Crystal Orientation in Electrodeposited Metals.' *Jnl. Electrochemical Soc.*, 1954, vol. 101, Sept., pp. 456–60.

Previous investigations on the influence of variables on the crystal structure of electrodeposits have dealt mainly with factors normally present in deposition, e.g., temperature of operation, bath composition and current density. In the present work two purposely superimposed conditions are studied.

Effect of Rotation of Cathode

These tests were made on electrodeposits of nickel, iron, silver, copper and antimony. Observations on nickel and iron show that where rotation of the cathode decreases current efficiency crystal orientation may be destroyed by such action. Loss of crystal orientation in these cases is presumed to be due to disturbances caused by the excessive amounts of co-deposited hydrogen on the rotating cathode. If rotation of the cathode causes a marked increase in current efficiency, the deposited crystals may change from the type of orientation which would be characteristic of deposits made from a similar bath on a stationary cathode, to the type in which the most densely

packed lattice plane is parallel to the substrate. This change is illustrated by deposits of silver and of copper made from cyanide baths. If rotation causes little or no change in current efficiency the crystal orientation of the deposit also remains unaltered, a condition which is characteristic of copper deposited from a sulphate bath and of antimony deposited from a chloride solution.

Effects of a Magnetic Field were studied on nickel, iron, and cobalt deposits made from sulphate baths. Under the conditions employed, the presence of a magnetic field of 5400 gauss, applied either perpendicular or parallel to the cathode, had no effect on the type of crystal orientation, but when the field was perpendicular to the cathode the surfaces of the deposits became very rough, and were covered with projections protruding in the direction of the field. A possible explanation of this phenomenon is advanced.

Electrodeposition of Bright Nickel from Solutions containing Thiourea

L. I. ANTROPOV and S. YA PAPOV: 'Influence of Thiourea on the Electro-Crystallization of Nickel.' *Jnl. Applied Chemistry, U.S.S.R.*, 1954, vol. 27, pp. 206–9; *Jnl. Applied Chemistry* (*Lond.*), 1954, vol. 4, Oct., ii, p. 446.

'Formation of bright nickel deposits from electrolytes containing thiourea is studied. Best results were obtained at 40°–45° by depositing nickel on a bright copper deposit, from a bath of the following composition:—

	g./L.
$NiSO4.7H_2O$	200
$Na_2SO_4.10H_2O$	80
H_3BO_3	20
NaCl	10
Thiourea	0·2–0·3

operating at a current density of 3–4 amp./sq. dm.'

Interrelation of Stress in Nickel Deposits and Endurance Limit

L. H. CURKIN and R. W. MOELLER: 'Stress Effect of Iron Contamination in a Watts-Type Nickel Plating Solution and its Correlation with Endurance Limit.' *Plating*, 1954, vol. 41, Oct., pp. 1154–7; disc., pp. 1157–8.

Full form of paper referred to from abstract source in *Nickel Bulletin*, 1954, vol. 27, Nos. 7–8, p. 129.

Stress increments resulting from additions of ferrous chloride to a purified nickel-plating solution of the Watts type were measured by two methods:—(1) the Brenner–Senderoff spiral contractometer, which indicates the change in a helix during plating (from which stress may be calculated), and (2) the optical interferometer, which utilizes an optical flat in contact with the polished unplated side of the specimen, to produce interference fringes. Analysis of this pattern, as recorded on a photographic negative, provides the basis for stress calculations. (Apparatus constructed for measurement by method 2 is illustrated.) Degree of correlation of unit stress with fatigue and endurance limit was determined by 'staircase' testing, in a rotating beam fatigue test. Groups of twenty similar specimens were compared with a similar group of unplated specimens by running each specimen to failure or to run-out (10^7 cycles without failure). A pre-determined increment of load, above or below that applied to the preceding specimen, was used, depending on whether the preceding one had run out or failed. The mean endurance limit calculated from an average of these data is taken as the point at which one half of the specimens could be expected to fail.

The results are summarized in the table below.

It will be observed that the values found indicate close correlation between increased stress and reduction in fatigue limit.

	Endurance Limit		Reduction in Endurance Limit		Indicated Stress on Test Panel	
	p.s.i.	t.s.i.	p.s.i.	t.s.i.	p.s.i.	t.s.i.
Unplated bar (S.A.E./A.M.S. 6322)* Rockwell C40	86,400	38·5	—	—	—	—
Plated from Watts-type solution, purified	71,200	31·8	15,200 (18%)	6·8	18,500	8·25
Plated from Watts-type solution, 0·2 g./L. Fe added	61,300	27·4	25,100 (29%)	11·2	27,500	12·3
Plated from Watts-type solution, 0·4 g./L. Fe added	55,200	24·65	31,200 (36%)	13·9	39,500	17·6
All Specimens baked 3 hours at 375°F. (190°C.) after plating.						

*Carbon 0·38-0·43, nickel 0·55, chromium 0·5, molybdenum 0·25, per cent.: similar to A.I.S.I. 8740.

Electrochemical Method for Testing Nickel Coatings

W. J. PIERCE and W. L. PINNER: 'An Electrochemical Method for Evaluating Plated Coatings.' *Plating*, 1954, vol. 41, Sept., pp. 1034–42; disc., p. 1042.

After a brief survey of the shortcomings of methods which have previously been proposed for testing electrodeposited metal coatings, the authors report experiments with the corrosion cell proposed by SHOME and EVANS (*Jnl. Electrodepositors' Tech. Soc.*, 1950, vol. 26, p. 137).

Observations made during these tests led to development of modified forms of test cell, for use (*a*) in the laboratory, and (*b*) in production control. Design and operation are described and illustrated. The influence of various factors, on the behaviour of nickel coatings under the new test, was investigated, e.g., thickness of coating, preparation of the basis metal before plating, manipulation of the plating bath.

In order to check the grading of electrodeposits subjected to the electrochemical test, service-exposure trials were made by placing panels similarly coated at the bumper position on automobiles which were driven an aggregate of 125,000 miles in winter conditions. A third set of panels was subjected to salt-spray test.

At the conclusion of this triple test it was found that the condition of the service parts had been accurately predicted by the results of the corrosion-cell test, whereas salt-spray tests did not yield data which could be interpreted in terms of expected resistance to corrosion under service conditions.

It is considered that the new test provides quantitative data in terms of number of holes, which can be statistically evaluated, and that it gives also useful qualitative information with regard to roughness, inclusions and irregularity in thickness of coating. The information provided by the research has also shed new light on the nature of corrosion in service. The theoretical aspect is briefly discussed as a conclusion to the paper.

Uses of Nickel in the Automobile Industry

H. H. HANSEN: 'The Automobile Industry as a User of Metals.' *Metall*, 1954, vol. 8, Oct., pp. 789–91.

This review is one of a series relating to the use of metals in various branches of the German industry.

Following an introduction in which statistics are given relating to total use of metals in automobiles, the applications and consumption of individual non-ferrous metals of major interest are discussed, viz., copper, aluminium, nickel. Most of the nickel used on automobiles in Germany is as underplating to chromium, for bumpers and other parts. The writer emphasizes that nickel is indispensable in this industry: recent restrictions on availability of the metal led to strenuous endeavours to develop substitute coatings, but the search proved the outstanding value of nickel as an undercoat, since none of the substitutes gave adequate corrosion-resistance.

Electrolytic Nickel-Clad Steel Plate

S. G. BART: 'Electrolytic Nickel-Clad Plate Offers Low-Cost Corrosion Protection.' *Iron Age*, 1954, vol. 174, Oct. 28, pp. 87–9.

This article describes Lectro-Clad steel, a product developed by Bart Manufacturing Corporation, Belleville, N.J. The material is designed to bridge the gap between electrodeposited coatings of normal thickness, and roll cladding, a process which does not provide for a 5 per cent. cladding on plate less than $\frac{1}{2}$-in. thick. Plating thicknesses of 0·006–0·020 in. are obtainable in Lectro-Clad. This material is the direct outcome of a process developed for nickel-lining of seamless steel pipe and fittings for use in atomic-energy plant and in various branches of the chemical industries. By dint of the strong and consistent adhesion obtained, the Lectro-Clad material can be subjected to heavy forming operations: it is also easily flame-cut and sheared.

Practices normally followed in high-grade nickel plating are standard in production of Lectro-Clad: an outstanding feature of the process is the preliminary cleaning, a double cycle of which is followed by anodic etching in sulphuric acid solution. The plating solution used is a modified Watts type, operated at 145°–155°F. (63°–74°C.). Metal concentration is kept at a high level, in order to permit operation at high current densities and yet assure even distribution of metal over the large surfaces involved. An essential feature of control is daily testing of pH, nickel-sulphate and nickel-chloride contents, and surface tension. The solution is purified at high pH with nickel carbonate, at frequent intervals, and is also continuously purified by low-current-density plating, to remove copper and other impurities.

Extensive routine tests ensure the properties required in the finished products. After final rinsing, a 30-minute porosity test is made in an aerated hot-water bath, and adherence is assessed by heating of the plated steel at several points to a temperature above 1200°F. (650°C.) and examination for resultant blistering. In addition, porosity, ductility, and hardness tests are made on sampling tabs which, welded to the racks, go through the plating cycle with the sheet. Micrographic examination is periodically made of sections sheared from treated plates. Lectro-Clad plating has a hardness of 140–160 Vickers; the tensile strength of the plated material is 50,000 p.s.i. (22·35 tons per sq. in.), and elongation is 30 per cent. in 2 in.

NON-FERROUS ALLOYS

Constitutional Studies on Ternary Alloy Systems: Bibliography

H. SPENGLER: 'History and Present Position of Research on the Constitution of Metals and Alloys. Ternary Metal Systems.' *Metall*, 1954, vol. 8, Sept., pp. 695–8.

(Reference to earlier instalments of this series is

given in *Nickel Bulletin*, 1954, vol. 27, Nos. 7-8, p. 130.)

The literature of the ternary alloys is listed in three sections, relating, respectively, to:—

(1) Systems in which the elements are completely miscible in both the solid and the liquid states.
(2) Systems in which there is complete or partial miscibility in the liquid state and which are completely or partially immiscible in the solid state.
(3) Systems in which the elements form intermetallic compounds, which in turn form eutectic or peritectic phases among themselves or with the elements comprising the alloy.

Metallurgical Reference Data for Engineers

See abstract on p. 222.

Electrical Resistance of Nickel Alloys in Magnetic Fields

H. C. VAN ELST and C. J. GORTER: 'The Ferromagnetic Anisotropy of the Specific Resistance of Some Nickel Alloys.' *Applied Scientific Research*, Sect. B, 1954, vol. 4, No. 1-2, pp. 87-90.

This paper reports results of measurements of the specific resistance of alloy rods in magnetic fields up to 20,000 Oersted, at 77°, 64°, 20°, and 14°K. (−196°, −209°, −253°, and −259°C.). The alloys for which data are presented are of the following types:—

Nickel-iron.
—cobalt.
—copper.
—iron-copper.
—aluminium.
—silicon.
—vanadium.
—chromium.
—manganese.
—molybdenum.
—palladium.
—tin.
—tungsten.

Shaping of Monel Fan Hubs by Blasting

'Dynamite Blast Production Costs in Forming Blower Hub.' *Iron Age*, 1954, vol. 174, Oct. 7, p. 70.

This article describes (with illustrations) a novel method of fabrication developed by an American firm for production of fan hubs of industrial blowers. Two welded Monel cylinders are telescoped, and placed in a laminated die. This is partially filled with water, and a stick of dynamite is suspended at water level. Next, a heavy cover is placed on the top, closing the die cavity. The explosive is detonated, expanding the cylinders into a double-walled fan hub which requires no trimming or heat-treatment. It is reported that both the base metal and the welds stand up well to this procedure. Monel has been chosen for the hub and other parts in order to give resistance to corrosive industrial gases which the blowers are designed to handle.

Induction Heat-Treatment of Nickel Silver

H. ROHN: 'Low-Frequency Induction Heating of Nickel Silver.' *Metall*, 1954, vol. 8, Oct., pp. 779-80.

The author gives some theoretical calculations, supported by practical experience, for current requirements and conditions necessary for low-frequency induction heating of nickel silver. Experimental data relate to annealing of two nickel silver alloys and of copper.

Gas Evolution and Gas Permeability of Nickel and Other Metals

See abstract on p. 223.

Nickel-Aluminium Alloys: Oxidation-Resistance and Physical Properties

R. L. WACHTELL: 'An Investigation of Various Properties of NiAl (including Corrosion-Resistance).' *U.S. Atomic Energy Commission Publn. WADC-TR-52-291*, 1952; 15 pp.; *Metallurgical Abstracts*, 1954, vol. 22, Sept., pp. 33-4.

'A study has been made of the preparation, fabrication and properties of the compound NiAl. This and the modified composition NiAl+5 per cent. nickel were prepared by powder-metallurgy methods. The oxidation-resistance, in air, of properly fabricated alloys of these compositions is excellent up to 1090°C. Weight gains were of the order of $1 \cdot 25$ mg./cm.^{2} after 300 hours' exposure. Maximum values of room-temperature modulus of rupture of $1 \cdot 44 \times 10^5$ p.s.i. have been attained, and indications of some ductility before fracture have been observed. Thermal-shock resistance of these alloys is good, and they show good resistance to attack by red and white fuming nitric acid at room temperature. Resistivity values of 20-30μ Ωcm. indicate a metallic behaviour. The thermal expansion coefficient is $15 \cdot 1 \times 10^{-6}$/°C. The alloy can be successfully forged.'

Nickel-Tantalum Alloys

I. I. KORNILOV, and E. N. PYLAEVA: 'Constitutional Diagram of the Nickel-Tantalum System.' *Isvest. Sektora Fiz.-Khim. Anal., Akad. Nauk S.S.S.R.*, 1953, vol. 23, pp. 110-17.

The alloys studied contained up to 59·04 per cent. tantalum. A summary of the observations made is given in *Chemical Abstracts*, 1954, vol. 48, p. 9299.

Nickel Alloys Showing High Secondary-Emission Characteristics

A. BOBENRIETH, J. MILLET and S. TESZNER: 'Alloys of High Secondary-Emission Capacity.' *Comptes Rendus*, 1954, vol. 239, Oct. 4, pp. 794-6.

Study of binary nickel alloys containing up to 4 per cent. of beryllium or up to 1·2 per cent. magnesium. The former type showed considerably higher secondary-emission properties than the latter. The nickel-magnesium alloys proved difficult to produce.

Preparation of Tensile Test Specimens in Thin Cupro-Nickel Strip

R. L. DOWDELL and W. B. F. MACKAY: 'Tension Specimens made by Photoengraving Technique.'
Bull. Amer. Soc. Testing Materials, 1954, No. 201, Oct., pp. 65–6.

Metal aperture masks used in the large picture tube of tricolour television receivers are now being made of 95–5 copper-nickel alloy. The thousands of 0·008-in. diameter apertures in the finished mask are produced by etching out the metal by a photoengraving technique.

Preparation of tensile test specimens of the thin alloy strip by conventional mechanical methods was found to result in somewhat erratic test results, but a satisfactory solution of the problem has been reached by adopting, for preparation of these specimens, the same technique as is used for producing the mask apertures. The following description is given of the procedure employed:—

'The strip is first coated with a photoengraving top enamel, and a phototransfer of the test specimen outline is made. The strip is washed, to dissolve out the unexposed portion, and the remaining enamel is burned-in at a low temperature, to make it more resistant to ferric-chloride etching, so that the complete outline of the tension specimen is etched out. The phototransfer is made on both sides of the strip. After the customary development and drying of the enamel, the strip is etched from both sides simultaneously, with an ordinary ferric-chloride solution used in photoengraving technique. The edges of these etched-out specimens are slightly double bevelled.'

Specimens so produced are found to give much more consistent tensile-test results than those made by mechanical methods. The authors suggest that although the process described is far from being universally applicable, it may be recommended for some other applications in which thin-gauge material is involved. The etching process avoids formation of disturbed metal along the edges of the specimens, thus ensuring an edge condition practically free from superimposed stresses.

NICKEL-IRON ALLOYS

Constitutional Studies on Ternary Alloy Systems: Bibliography

See abstract on p. 226.

Electrical-Resistance of Nickel Alloys in Magnetic Fields

See abstract on p. 227.

Nickel-Alloy Magnets in Coolant Separators

'Magnetic Coolant Separators.' *Engineer*, 1954, vol. 198, Oct. 29, p. 607.

An illustrated description of a typical 'Barnesdril' separator, which extracts ferrous particles and entrained abrasives from coolants. The separator works by means of a slowly rotating drum which is magnetized by internally arranged Alcomax (nickel-aluminium-cobalt-iron-alloy) magnets.

Electrieal Resistance of High-Permeability Nickel-Iron Alloys containing Molybdenum

B. G. LIVSHITS and M. P. RAVDEL: 'Electrical Resistance of Ni_3Fe Alloys containing Molybdenum.'
Doklady Akad. Nauk S.S.S.R., 1953, vol. 93, pp. 1033–5.
Jnl. Applied Chemistry, (Lond.) 1954, vol. 4, Sept., pp. 342–3.

'Addition of molybdenum to Ni_3Fe reduces the linear increase in its specific conductivity with per cent. reduction in area which is normally observed, and at more than 1 per cent. of molybdenum there is actually a decrease. An alloy containing 5 per cent. molybdenum shows maximum specific conductivity at 450°, whereas pure Ni_3Fe has a minimum at that temperature. The dilatometric curve for Ni_3Fe containing 5 per cent. of molybdenum does not show the sudden increase (followed by a decrease) of volume at 550°C. shown by the molybdenum-free material, but simply a change to a lower coefficient of expansion. The curve for an alloy containing 1 per cent. of molybdenum shows the first effect at 550°C. and the second at about 650°C. The interpretation offered by the authors is that molybdenum eliminates the ordered structure of Ni_3Fe at low temperature and replaces it by segregation of molybdenum and iron.'

Gas Evolution and Gas Permeability of Nickel and Other Metals

See abstract on p. 223.

Nickel-Iron 'Ferrites'

J. K. GALT: 'Motion of Individual Domain Walls in a Nickel-Iron Ferrite.' *Bell System Technical Jnl.*, 1954, vol. 33, Sept., pp. 1023–54.

The mechanism which contributes most to the permeability of high-permeability magnetic materials is the motion of ferromagnetic domain walls. These walls are thin lamellae in which the direction of the spontaneous magnetization of the material changes from one domain to another. As a result, this mechanism contributes a major part of the energy losses which accompany rapid changes in the direction of the magnetization in such materials. It is well known that in the ferromagnetic metals these losses usually arise from the eddy currents which are induced by the motion of the domain walls. In the 'ferrites', however, the conductivity is so low that the contribution of eddy currents to the losses is never overwhelming, and is often negligible. The losses must therefore arise, in large part, from other sources not yet understood. The authors of this paper present some recent studies of these losses and discuss their significance in relation to losses in 'ferrites' in general.

Samples were cut from single crystals of the nickel-iron 'ferrite' $(NiO)_{0·75}$ $(FeO)_{0·25}$ Fe_2O_3, in such a way that they contained only one movable ferromagnetic domain wall. The viscous damping coefficient for this wall, which is a measure of the losses associated with domain-wall motion in this material, was measured as a function of temperature. The damping showed a very large increase when the temperature was lowered to about 77°K. (−196°C.). By means of

theoretical analysis data previously available, the damping value was correlated with the Landau-Lifshitz equation for the rotational motion of magnetization. In addition, it is suggested that the sharp increase in damping observed at low temperatures is due to a relaxation associated with a rearrangement of the valence electrons of the divalent and trivalent iron ions in the 'ferrite'. A tentative phenomenological theory of the losses, based on this mechanism, is proposed.

CAST IRON

Resistance of Nickel-Alloy Cast Irons to Soil Corrosion

'Corrosion of Nickel Cast Irons in Soils.'
Bull. Amer. Soc. Testing Materials, 1954, No. 201, Oct., p. 29.

Short summary of results obtained in extensive series of tests made by the National Bureau of Standards, at sixteen exposure sites, representing various types of soil. The efficacy of relatively high nickel in cast iron, in conferring resistance to corrosion, is clearly demonstrated. The full report was abstracted in *Nickel Bulletin*, 1954, vol. 27, No. 4, pp. 73–4.

Metallurgical Reference Data for Engineers

See abstract on p. 222.

HEAT- AND CORROSION-RESISTING MATERIALS

Equipment for Study of Cyclic Thermal Stresses in Metallic Materials

L. F. COFFIN and R. P. WESLEY: 'Apparatus for Study of Effects of Cyclic Thermal Stresses on Ductile Metals.' *Trans. Amer. Soc. Mechanical Engineers*, 1954, vol. 76, Aug., pp. 923–50.
L. F. COFFIN: 'A Study of the Effects of Cyclic Thermal Stresses on a Ductile Metal.' *ibid.*, pp. 931–49; disc. pp. 949–50.

In service conditions in which very high rates of heat transfer exist, as in nuclear reactors, severe thermal stresses can be developed in structural materials. These stresses can be relieved by plastic flow and, consequently, are not regarded as serious when steady-state conditions prevail. Under the action of thermal oscillations, however, cyclic thermal stresses are developed, and, in some conditions of frequency of cycles and severity of thermal stress, fatigue failure may result. Chromium-nickel steels of the 18-8 type, due to their low thermal conductivity and high thermal expansion, are particularly prone to this effect.

In the Knolls Atomic Power Laboratory, operated by General Electric Company, U.S.A., investigations have been under way for some time with the dual purpose of obtaining information on the resistance of individual materials to thermal fatigue, and of learning more of the fundamental aspects of the problem, in order to secure a more intimate understanding of the phenomena of fatigue. The first of these two papers describes equipment and technique developed for thermal-stress testing; the second covers results of tests made, by that method, on Type 347 (niobium-stabilized) 18-8 chromium-nickel steel. In the procedure used, a cyclic temperature is imposed on a thin tubular test specimen subjected to complete longitudinal constraint. The cyclic strain is thus the independent variable.

The report gives results of tests made to determine: (*a*) effect of thermal stress-cycling on strain hardening and life-to-failure for a fixed mean temperature, (*b*) effect of degree and kind of previous cold work, on strain hardening and cycles-to-failure, (*c*) effect of mean temperature on thermal-stress cycling, (*d*) effect of period of cycle on cycles-to-failure, and (*e*) effect of prior strain cycling on stress-strain characteristics.

The following conclusions are drawn with regard to the specific material examined:—

'1. For a fixed mean temperature, variations in the cyclic temperature change resulted in a characteristic fatigue curve of temperature change *vs.* cycles-to-failure.

'2. In contrast to cases in which stress is the independent variable, with thermal-stress cycling prior cold work can reduce the number of cycles-to-failure when the strain is severe, but it is beneficial when the strain amplitude is low. When stress is the independent variable, cold work is beneficial (unless the material is damaged during the deformation).

'3. The kind of prior cold work was found to be unimportant in thermal-stress cycling. For the same prior effective strain and cyclic-temperature change, specimens cold-worked by torsion withstood about the same cycles of thermal stress as specimens cold-worked by tension.

'4. When the mean temperature is increased while a constant temperature change is maintained, a marked decrease in cycles-to-failure is found.

'5. No significant difference in the life-to-failure was observed between specimens clamped in the test apparatus during the high-temperature-holding phase of the cycle and the low-temperature phase.

'6. A decrease in cycles-to-failure with increased holding time during thermal cycling was observed. However, the time for failure increased with increasing holding time.

'7. Prior thermal-strain cycling was found to have little effect on the elevation of the subsequent true stress-strain curve. A marked decrease in fracture ductility occurred, however, as the number of prior strain cycles was increased. Scatter in ductility was quite wide. For example, after 8,000 prior cycles some specimens had failed completely, while others maintained the ductility of the initially annealed specimens. The scatter was a result of the variations in occurrence and size of fatigue cracks formed during thermal-stress cycling: these cracks act as stress-raisers during the tension test. This was substantiated by the strikingly similar behaviour found in a test specimen containing a 13-mil hole and subjected to tension.'

From the measurements and observations made in

the tests on the 18-8 chromium-nickel steel, certain general conclusions are drawn regarding the nature of the fatigue process: these are found to be in general agreement with those of other investigators. From the evidence thus accumulated, the author proposes a mechanism to explain the behaviour of ductile metals under cyclic loading conditions.

Centrifugal Casting of Turbine Casings in Austenitic Nickel-Chromium Steel

'Proteus Turbine Casing Produced by Centrifugal Casting.' *Machinery* (*Lond.*), 1954, vol. 85, Sept. 24, pp. 647-52.

This article contains a detailed and well illustrated account of methods used in the foundry of Sheepbridge Alloy Castings, Ltd., Sutton-in-Ashfield, for production of turbine casings in Thermax heat-resisting steel (nickel 12, chromium 23 per cent.). Casting, machining, heat-treatment, finishing, and inspection methods are reviewed.

Machining of Nimonic Alloy Turbine Blading for the Dart Turbo-Prop Engine

'Machining Turbine Blades for the Dart Propeller Gas-Turbine Unit.'
Machinery (*Lond.*), 1954, vol. 85, Oct. 22, pp. 855-66.

The Rolls-Royce Dart propeller gas-turbine engine, already well known as the power unit of the Vickers Viscount airliner, has been specifically designed to meet the needs of civil aviation. Research on propeller gas turbines was begun by Rolls-Royce in 1944, and the original Dart engine, which was in service by 1946, developed 1,000 h.p., which was subsequently raised to 1,400 h.p. augmented by 365 lb. thrust. At this power it went into service with British European Airways. Further development has increased the output to 1,550 h.p. at 14,500 r.p.m., at which speed the specific fuel consumption is 0·77 lb. per horse power per hour. Production of this latest form of the Dart will start in 1955.

This article gives a brief general note on the design of the engine, followed by a well-illustrated description of machining operations carried out in production of turbine blades. These are of the nickel-chromium alloy Nimonic 80A, which, together with Nimonic 90, a nickel-chromium-cobalt alloy, is a standard blading material in British gas-turbine aircraft engines. Another alloy of the same series used in the Dart engine is Nimonic 75, from which the seven combustion chambers are made.

Nickel-Chromium-base Alloys for High-Temperature Applications

J. O. HITCHCOCK: 'Heat-Resisting Nickel-Chromium-base Alloys for Gas Turbines and Other Industrial Applications.'
Reprint from Revue de la Société Royale Belge des Ingénieurs et des Industriels; 16 pp.
Issued by Centre d'Information du Nickel, Brussels, 1954.

A review is made of the gradual development of nickel-chromium-base alloys, from the patents assigned to Marsh in 1908, through to the complex heat- and creep-resisting alloys used during and since the war period. The properties significant in materials for high-temperature applications are discussed:—creep-resistance, fatigue-resistance, thermal expansion, thermal conductivity, stability, resistance to high-temperature corrosion, ease of fabrication. In the light of the requirements essential for this type of service, the author reviews the properties of the Nimonic nickel-chromium-(cobalt)-base alloys. Composition limits are quoted for Nimonic DS, 75, F, 80/80A, 90 and 95, and details are given of the creep-test requirements of specifications to which the 80, 80A, 90 and 95 alloys are supplied. The characteristics of the individual alloys are discussed, with tabular information on physical and mechanical properties, creep-resistance and fatigue strength. The information covers, in appropriate cases, room-temperature as well as elevated-temperature properties. Particular attention is devoted to the applications of the respective materials in gas turbines, and reference is also made to some of the other uses for which they have already proved particularly suitable. Among these are high-temperature valves, springs, dies, conveyor belts, furnace parts, glass-making equipment. Typical applications are illustrated.

Nickel Alloys in Fastening Components for High-Temperature Service

J. L. EVERHART: 'Fasteners for High-Temperature Service.' *Materials and Methods*, 1954, vol. 40, Sept., pp. 104-6.

Among the properties required in nuts, screws, bolts and other types of fastener used in high-temperature engineering are stability at the operating temperature, resistance to shock (both mechanical and thermal), and freedom from susceptibility to embrittlement. Such characteristics must be guaranteed, in addition to the mechanical and physical qualities essential in such components working in normal temperature ranges.

This article describes and illustrates some examples of fastening components which have been successfully used, and discusses the importance of design and materials. Properties typical of chromium-nickel steels, and cobalt- or nickel-base alloys which may be considered for such applications are tabulated.

Nimonic Springs for Suspension of Work during Heat-Treatment

'Nimonic Springs Solve Hot-Handling Problem.'
Machinist, 1954, vol. 98, Oct. 8, p. 1791.

Difficulties in suspension of tools during heat-treatment have been solved in the works of Firth-Brown Tools, Ltd., by the adoption of springs to suspend the work from the holders. The drills, or any other tools having tapered shanks, are inserted into the springs with a slight twist, and expansion of the end coil results in sufficient tension on the spring to effect firm gripping. Assembled on a holder, the tools are lowered first into the pre-heating salt bath, where the temperature is raised to about 850°C., and are then

transferred, for soaking, to the high-temperature Carboneutral salt bath, which is run at about 1300°C. Removal of the tools from the holders is as simple as assembly, permitting much saving in time and labour costs, and thus increasing productivity.

The material first tried for the springs, a normal grade of spring steel, failed prematurely, due to softening and resultant deterioration of properties, but springs of Nimonic 90 (nickel-chromium-cobalt-base alloy) have proved entirely satisfactory. Not only does this alloy provide the required strength at the operating temperatures, but it is also highly resistant to oxidation and scaling, and is suitable for continuous heating and cooling. The life of the springs cannot as yet be determined, since some which have been in daily use for nearly a year are stated to be still as good as new, with a prospect of several years of service.

Insulated Nickel-Chromium Alloy for Wire-Wound Resistances

HENRY WIGGIN AND CO., LTD.: 'Oxy-Insulated Brightray B.'* *Publn.* 766, 1954; 4 pp.

Tubular wire-wound resistances of nickel-copper (Ferry) wire are usually close wound on ceramic or enamelled steel tubes, in order to occupy minimum space. Under normal load the surface temperature of these resistances is about 250°-300°C., and the insulation necessary to prevent shorting between the turns is provided by the oxide coating which forms on the alloy wire at such temperatures. Since the potential difference between adjacent turns is fairly small, oxidized Ferry is satisfactory for such applications.

In cases for which the resistance of Ferry is too low to permit of the number of ohms being provided within the space available, Brightray B (nickel-chromium-iron alloy) is used. The oxide normally produced on this alloy has, however, low insulating properties, and close winding of wire of this composition would be unsatisfactory. The problem has been solved by development of a special surface-treatment process: the Brightray B wire is plated with nickel, which is subsequently oxidized. Wire so treated has insulation values completely adequate for all normal close-wound resistances.

This publication describes a special testing technique which has been devised for determining the insulation value of the oxidized-nickel-coated wire and gives details of the requirements to which the resistance wire must conform.

Brazing of Nickel-containing High-Temperature Alloys

F. C. KELLY: 'Dry-Hydrogen Brazing for High-Strength Alloys.' *Product Engineering*, 1954, vol. 25, Aug., pp. 156-60.

This article is based on the experience of the General Electric Company, U.S.A. The advantages of dry-hydrogen brazing are urged, with details of typical cases in which this method can be used for assembly, on a production basis, of components of stainless steels, nickel-chromium-base alloys, silicon steels and cobalt-chromium-base alloys. A step-by-step description of the process is given (diagrammatically illustrated), joint design is discussed (with drawings), and some data on the strength of brazed joints made in various materials are tabulated.

* *We shall be pleased to supply a free copy of this publication.*

Metallurgical Reference Data for Engineers

See abstract on p. 222.

Standard Samples of Austenitic Nickel-Chromium Steels

'Stainless Steel Spectrographic Standards.' *Bull. Amer. Soc. Testing Materials*, 1954, No. 201, Oct., p. 83.

The National Bureau of Standards announces availability of three stainless-steel spectrographic standards of the 18-8 chromium-nickel type. The standards are issued in the form of rods $\frac{7}{32}$ in. in diameter and 4 in. long.

The provisional certificate of analysis gives limits for nine minor and trace constituents:—aluminium 0·0003-0·0025, boron 0·0005-0·0033, copper 0·11-0·24, lead 0·002-0·004, molybdenum 0·12-0·22, niobium 0·03-0·21, tungsten 0·08-0·18, vanadium 0·032-0·12, zinc 0·003-0·005, per cent. The samples are numbered 442, 443, 444.

Production of Extra-Low-Carbon Stainless Steel

R. W. WEESE: 'Improved Process Control Assures Economical Production of Extra-Low-Carbon Cast Stainless.' *Iron Age*, 1954, vol. 174, Oct. 14, pp. 133-5.

Restriction of the carbon content of 18-8 and 18-8-Mo chromium-nickel steels to a maximum of 0·03 per cent. is found to give an added margin of safety against corrosion, but the large-scale production of material to such close limits involves strict control at all stages of manufacture. This article is based on the experience, in production of steel castings, of Electric Steel Foundry Company, Portland, Oregon, where oxygen lancing is a feature of normal procedure.

In this foundry the requisite control starts with purchase of carefully selected scrap material. Both the carbon- and alloy-steel scrap is sorted to avoid contamination with non-ferrous and other materials which might prove detrimental, and most of the high-alloy scrap is pre-melted in pig heats, in order to determine its exact chemical composition and purity.

It has been found that the use of arc furnaces permits much closer control of carbon content than is possible with induction furnaces. The arc furnaces are basic-lined, and control of slag basicity is very critical, in order to avoid carbon pick-up or frothing of the slag. Basicity must be kept low until the last few moments of the heat, and the lime content of the slag is then raised, to obtain recovery of chromium. A certain minimum bath temperature must be reached before injection of oxygen: it is introduced, at this stage, directly into the molten steel, at a pressure of 110 p.s.i., through a lance protected by ceramic material. Time of oxygen treatment is calibrated with the volume of metal being treated and with the initial

carbon level. The average carbon contents of heats produced over various periods are given in this article, showing that, by the use of the procedures described, a guaranteed maximum carbon content of 0·03 per cent. can be ensured.

The following tables give compositions and properties typical of steels being manufactured under these conditions.

As a result of the growing use of extra-low-carbon stainless steels in atomic-energy plant and in industrial applications, a number of specifications for corrosion-testing after sensitizing treatment have been developed. One of the most widely accepted in the U.S.A. requires that the specimen be sensitized for one hour at 1250°F.±10°F. (675°C.±5°C.), water-quenched, and then subjected to 65 per cent. boiling nitric acid solution for five 48-hour periods. Average corrosion rate for the five periods must not exceed 0·002 in. penetration per month. It is stated that a substantial proportion of the cast steel made by Electric Steel Foundry Company has shown an average of only 0·0015-0·0018 in. per month. Data from Huey nitric-acid corrosion tests made by independent authorities are cited in confirmation of the satisfactory characteristics of the steels.

Table 1

Steel to Specification	C %	Si %	Mn %	Cr %	Ni %	Mo %
A.I.S.I. 304L	0·015-0·025	0·70	0·81	19·4	9·7	—
A.I.S.I. 316L	0·015-0·025	0·68	1·13	19·8	9·7	2·8

Table II
Mechanical Properties of Extra-Low-Carbon Stainless Steels

Steel to Specification	Tensile Strength		Yield Strength		Elongation	Reduction of Area	Brinell Hardness
	p.s.i.	t.s.i.	p.s.i.	t.s.i.	%	%	
A.I.S.I. 304L	68,000	30·5	33,000	14·75	56	75	134
A.I.S.I. 316L	79,500	35·5	45,000	20·0	46	62	163

Determination of Ferrite in Niobium-Stabilized Stainless Steel

W. L. FLEISCHMANN: 'Determination of Ferrite in Type 347 Stainless Steel Weld Deposits.'
Welding Jnl., 1954, vol. 33, Sept., pp. 459S-68S.

In order to obtain crack- and fissure-free welds in 18-8-Nb steel welds it is usual to adjust the chemical compositions of the electrodes and filler wires to produce deposits in which a small amount of ferrite is present within the austenitic matrix. The amount of ferrite desirable varies somewhat, but in certain applications it is necessary to limit it to a very low percentage, e.g., welds in high-temperature installations should have a low ferrite content in order to minimize liability to sigma formation and resultant embrittlement on prolonged exposure at elevated temperature. Welds forming part of machinery requiring to be constructed in non-magnetic materials should also be low in ferrite. In various specifications which have been drawn up to cover welding electrodes tests are laid down which are designed to reveal any behaviour which would result from excess ferrite, but little attempt has been made to provide for accurate estimation of the ferrite content of weld materials in which specially low percentages of this constituent are essential.

The present author points out the difficulty of establishing the ferrite content of an austenitic weld deposit, indicating (1) the limitations of assessment by the metallographic technique, and (2) errors inherent in calculation of ferrite content from chemical composition according to the Schaeffler diagram.

In the experimental work described, the problem was approached along two lines: (1) study of the variation in ferrite contents in individual lots of 18-8-Nb steel electrodes, and (2) evaluation of test methods which would permit measurement of ferrite content with reproducible accuracy. Under (2) an investigation was made of the d.c. magnetization curves of the steel and 'Magne-Gage' readings were taken, to ascertain whether this relatively inexpensive test could be safely substituted for complicated standard magnetic test methods; results of the two types of magnetic test were correlated with the microstructure of the steel; electrical-resistivity measurements were made to check variations which may occur in identical weld deposits, and, as a further check (since control of ferrite content is based on the composition of the wire and of the coating), the weld deposits were chemically analyzed by two independent laboratories. A brief study of the influence of deposition procedure, on the composition of the deposits, was undertaken in order to explain differences in analyses reported by the two laboratories.

As a result of the above tests, the author has reached the following conclusions:—

'1. The ferrite content in austenitic weld deposits

cannot be accurately determined from the nickel and chromium equivalents established for locating the ferrite percentage in the Schaeffler diagram.

(*a*) The calculation of the nickel equivalent should include nitrogen.

(*b*) With consideration of nitrogen in the nickel equivalent, there were indications that the chromium equivalent established by CAMPBELL and THOMAS (*ibid.*, 1946, vol. 25, p. 760) should be used.

(*c*) If ferro-tantalum-niobium is used, the tantalum equivalency should be adjusted, because the equivalent of tantalum is only one-half that of niobium.

'2. In order accurately to compare the composition of weld deposits, welding conditions must be standardized, since silicon, carbon, and nitrogen are affected by the length of the arc, and by current.

'3. Measurements of intrinsic induction gave consistent results and the values were not affected by the grain size of the ferrite phase.

'4. Magnetic properties established at low fields were found to be sensitive to grain size and are not, therefore, considered to be a good measure of the ferrite content in austenitic weld deposits.

'5. As Magne-Gage readings are made at low flux densities, changes in ferrite particle size affect the results. Magne-Gage tests are therefore not recommended for measurement of ferrite content.'

It is concluded that in drawing up specifications, saturation induction can be called for as a measure of the ferrite content. Nitrogen should be included in the nickel equivalency, and if part of the niobium is replaced by tantalum the lesser ferrite-forming tendency of tantalum should be taken into account in considering chromium equivalency.

Nickel-containing Materials in Chemical Engineering: Literature Survey

'Materials of Construction for Chemical Engineering.' 8th Edition of Materials of Construction Review. *Industrial and Engineering Chemistry*, 1954, vol. 46, Oct., pp. 2041–148.

The review is arranged in a manner similar to that used for earlier editions. In most cases the literature summarized covers one year; in the case of ceramics, hard rubber, copper and wood longer periods are involved, since these materials were not dealt with in the preceding issue. The scope of the individual sections is indicated below, with notes on items which are of particular interest in relation to nickel-containing materials:—

R. KATZEN: 'Copper and Copper Alloys', pp.2065–6.

A section of this review is concerned with copper-nickel alloys, drawing attention to the well-established uses of the 70–30 and 80–20 grades, and to more recent developments in iron-containing copper-nickel alloys of lower nickel content.

H. L. SHAW: 'Iron, Mild Steel and Low-Alloy Steels', pp. 2084–7.

The review includes reference to various types of lean-alloy steel, to investigations on mechanical properties, weldability, and corrosion-resistance. Methods adopted to conserve nickel (which, in the period reviewed, was still under control) are noted.

H. O. TEEPLE: 'Nickel and High-Nickel Alloys', pp. 2092–107.

As in previous years, the commercially important properties of nickel and nickel alloys have been the subject of detailed study by many investigators, and the resulting developments have helped in the solution of various industrial problems. This review, which is supported by a *bibliography* of 200 references, contains sections covering extraction and refining; the mechanical and general physical properties of the metal and its alloys; magnetic properties; high-temperature properties; nuclear characteristics and isotopes; fabrication (welding and brazing, mechanical forming, machining); plating; applications (in high-temperature engineering, and in chemical-processing and petroleum-processing equipment).

W. A. LUCE: 'Stainless Steels and Other Ferrous Alloys', pp. 2114–24.

The vital importance of nickel in the stainless-steel industry is emphasized in the literature reviewed, which has included papers dealing with modified types of stainless steel, testing of corrosion-resistance, uses of stainless types of steel in various applications, mechanical properties, phase transformations and structure (with particular interest in sigma phase), behaviour of steels in corrosive environments at normal and elevated temperatures, resistance to thermal shock, strength and ductility at elevated temperatures, welding and brazing. The literature on manufacture, mechanical working, and surface treatments is also summarized. The supporting *bibliography* numbers some 170 items.

Aluminium Alloys, pp. 2045–52.
Cements, pp. 2053–5.
Ceramics, pp. 2056–64.
Elastomers, pp. 2067–75.
Fibres, pp. 2076–83.
Lead and Lead Alloys, pp. 2088–91.
Paints, pp. 2108–11.
Hard Rubber, pp. 2112–13.
Tin and Its Alloys, pp. 2124–7.
Wood, pp. 2127–30.
Less Common Metals (Titanium, Zirconium, Molybdenum, Tantalum), pp. 2130–5.
Plastics, p. 2135–48.

Molybdenum-bearing Stainless Steels for Use in Chemical Plant

W. R. MYERS: 'Analysis for Molybdenum-bearing Austenitic Stainless Steel, Proposed for Experimental Use in Chemical and Process Industries.' *Bull. Amer. Soc. Testing Materials*, 1954, No. 201, Oct., pp. 28–9.

This article, prepared for the American Standards Association Chemical Industry Advisory Board Sub-Committee on Stainless Steel Analyses, is published for information, and to elicit comments, since the proposals made (*see below*) may eventually be incorporated in a specification.

The author reviews the history of the introduction

of molybdenum-bearing austenitic stainless steels into chemical-process equipment and briefly indicates the fields of application for which such steels are peculiarly suitable. Difficulties associated with the 'unbalanced' composition of the molybdenum-containing variants of the 18-8 steels are noted, and reference is made to specifications which have been drawn up to ensure good working characteristics combined with corrosion-resistance. The limits laid down in A.I.S.I. specifications for Types 316 and 317 are tabulated.

In some cases the molybdenum-bearing stainless steels actually used in industry do not conform to any standard specifications, and the Advisory Board for whom this summary has been prepared has recently made a survey of the practice, in this respect, of thirty-two companies representing a cross section of the chemical industry in the U.S.A. The replies to the questionnaire issued showed that nine of the companies use A.I.S.I. standard specifications, ten purchase to their own schedules (which vary from A.I.S.I. standards), and the remainder follow various practices, basing their requirements partly on standards and partly on their own specific preferences. The all-over conclusion is that the bulk of the molybdenum-modified austenitic nickel-chromium steels now used in American chemical industry conforms relatively closely to the limits laid down for the A.I.S.I. 316, and it is suggested that an endeavour should be made to obtain agreement on a standard composition range which would be acceptable to the whole of the chemical industry. The following composition is proposed, as being likely to ensure materials acceptable to at least 80 per cent. of the users:—

	%
Carbon	0·07 max.
Silicon	1·00 max.
Manganese	2·00 max.
Phosphorus	0·040 max.
Sulphur	0·030 max.
Chromium	17·5 min.
Nickel	9·5–12·5
Molybdenum	2·25 min.

The advisory Committee recommends that such specification be proposed for acceptance by the industries concerned and that the American Iron and Steel Institute, the American Society for Testing Materials, and the American Standards Association be asked to recognize it as standard.

Materials for Valves Used in Chemical Plant

'Valves to Combat Corrosion.'
Chemical Engineering, 1954, vol. 61, Sept., pp. 198–204.

This article is the outcome of a 'Valve Clinic' sponsored by Cooper Alloy Foundry Company, Hillside, N.J., which was recently held in various centres in the U.S.A. The meetings were attended by over 1,000 engineers concerned with all phases of valve construction and use, and their questions were answered by the chief engineer and the chief chemist and metallurgist of the Cooper Alloy Foundry Company. The information contained in the questions asked and the answers given has now been summarized in the form of a practical reference guide. The nature of the article precludes detailed abstraction, but the scope of the information which can be obtained by consultation of the original is indicated by the following skeleton of contents:—

Valve Materials suitable for handling sulphuric, hydrochloric, nitric, and mixed acids, caustic solutions, sour petroleum products, chlorine, brine, mercury, sodium chloride-glycerine, wet sulphur dioxide, molten sulphur.

Properties and relative advantages, for valve use, of titanium- and niobium-stabilized stainless steels, extra-low-carbon grades of stainless steel, titanium: packing materials: S Monel for valve trim.

Problems encountered in operation of valves: galling (hardsurfacing, special lubrication, electropolishing, regulation of relative hardness of mating surfaces, as preventives); distortion or creep, leading to leakage; handling of abrasive slurries; conditions involving long-time cut-off; magnetic characteristics as a criterion of the quality of austenitic valve materials.

What to look out for during installation and repair of valves: electrode materials for repair by welding; post-weld heat-treatment; welding of dissimilar materials; effect of resurfacing of seats by machining, on corrosion-resistance of nickel-chromium-iron gate valves; procedure for valve inspection.

Effect of Fabricating Procedures on Quality of Valves: corrosion of cast vis-à-vis wrought materials; heat-treatment of austenitic valve materials; case-hardening; precipitation-hardened valve materials; finishing operations and passivation, in relation to valve service.

Materials for Handling Fluorine

'The Corrosive Effects of Fluorine.' *Industrial Chemist*, 1954, vol. 30, June, pp. 266–8.

The need for materials which will withstand attack by fluorine has recently assumed added importance, in view of the probable significance of fluorine chemistry within the next few years. The purpose of this article is to review information which is available on methods used for handling fluorine, and to indicate problems which have not yet been solved.

Fluorine is the most reactive of all known elements; it attacks many metallic materials and reacts with many gases and chemical substances. With aluminium, nickel, iron and copper, attack at room temperature is limited to formation of a surface film, but at elevated temperatures reaction is in many cases vigorous and self-sustaining.

In general, metals which show resistance to oxidation, e.g., nickel and low-carbon and low-silicon irons, usually give good resistance, at low pressures, up to about 400°C. Stainless steels are not recommended for handling fluorine at temperatures above 250°C. and niobium-stabilized stainless steels exhibit a high rate of corrosion even at this temperature, due probably to formation of a volatile niobium pentafluoride. The presence of moisture, or of organic contaminants, is likely to enhance attack or initiate violent reactions which may lead to ignition.

The author makes reference to published literature in which the extent of fluorine attack on various metallic and non-metallic materials has been reported:

a brief summary of conclusions drawn from such data is given, from which the following is taken:-

It is reported that aluminium and magnesium are resistant to fluorine up to 450° and 300°C. respectively, while platinum corrodes very rapidly at 400°C. in the presence of fluorine and is quite unusable at this temperature. In general, nickel appears to be the most suitable material for high-temperature work up to about 600°C. If water vapour is likely to be present in the system, Monel is preferable, since this alloy gives better resistance than nickel to hydrofluoric acid. (The presence of hydrofluoric acid in fluorine normally increases the severity and rate of attack on metals.) Monel also has superior mechanical properties and should be used where abrasion may occur, for example in valve seats. A limitation to the use of nickel occurs where sulphur compounds are present, due to liability to intercrystalline corrosion, and embrittlement.

The behaviour of non-metallic and organic materials in contact with fluorine is also considered.

With regard to plant, the following are among the conclusions reached as a result of correlation of information from various sources:—

For normal plant work at low temperatures mild steel is quite satisfactory, and copper for temperatures above 250°C. to approximately 350°C. Nickel piping is satisfactory up to about 600°C. An all-welded system is to be preferred, and flanged joints should be held to a minimum. For permanent installations soft copper or aluminium is to be preferred as a gasket material rather than rubber, which will tend to corrode and ultimately disappear. Screwed piping is definitely unsatisfactory for fluorine service.

For high-pressure work Monel pipe has been found to be quite satisfactory up to at least 30 p.s.i.g. Sealing rings of annealed nickel, between properly designed flanges, should be used for service at elevated pressures.

Valves are vulnerable to leakage across the seats and at the valve stem. The resistance of metals to fluorine attack usually depends on the existence of a protective film of fluoride, and, because of the abrasive action involved in the turning of a valve, materials which show minimum scale formation, such as Monel and nickel, are preferred for valve stems and seats. Seat leakage in valves handling low-pressure fluorine can be largely eliminated by a suitable design, using non-metallic discs seating on Monel or nickel. Metal-seated valves with Monel or aluminium-bronze seat and disc combinations have also been used. Stem leakage can be prevented also by the use of Monel or copper bellows, silver-soldered to the stem and body of the valve, with the joints subsequently nickel plated.

For high-pressure service discs of aluminium alloy seating against Monel are reported to be satisfactory. There must be sufficient difference in hardness between the disc and the seat to ensure a gas-tight joint. A packing made of a compressed mixture of powdered nickel, shredded asbestos and graphite has also been successfully used. Since in any type of valve it is unsafe to presume that the seat will remain tight indefinitely, it is recommended that double valving be provided at all points where tightness is an important consideration. Bellows-sealed valves have been used up to 100 p.s.i.g. in 1-in. and larger sizes, and Monel needle valves packed with P.T.F.E.* have been successful up to 400 p.s.i.g. With fluorine under high pressure non-metallic seats or discs are not safe, and the problem of seat leakage is much more acute. Double valving is strongly recommended and valves should preferably be welded into the line.

In conclusion, it is urged that the dangers involved in handling chlorine should not be exaggerated. Provided that scrupulous cleanliness is ensured and that due consideration is paid to the effects of traces of water, there is no reason why the handling of fluorine should be hazardous.

Resistance of Nickel-containing Materials to Hydrofluoric Acid

M. SCHUSSLER, A. G. DOBBINS and D. S. NAPOLITAN: 'Metal Materials for Handling Aqueous Hydrofluoric Acid.' *U.S. Atomic Energy Commission Publn. K*-1080, 1953; 70 pp.

Metallurgical Abstracts, 1954, vol. 22, Sept., pp. 59-60.

The resistance of the following materials to attack by aqueous hydrofluoric acid (containing 48 or 5 wt. per cent. HF), at 150°F.±10°F. (66°C.±5°C.), was studied:—cold-rolled and annealed Monel, cold-rolled and annealed 70-30 copper-nickel alloy, Illium R (complex nickel-chromium-iron-base alloy), commercial lead, and fine silver. Some brazed and welded joints were also tested. The results are summarized as follows:—

'*Silver:* Low corrosion rates under all conditions: the most resistant of the materials tested.

'*Lead:* Not usefully resistant under the test conditions.

'*Illium R:* Badly pitted when totally immersed, and severely attacked at liquid level. Stress-corrosion cracks appeared in silver-brazed specimens.

'*Monel:* Good resistance (in both cold-rolled and annealed conditions) when totally immersed: welded and brazed joints were satisfactory. At and above the liquid level the corrosion rate was 20–100 times that of the totally-immersed material; the attack was not uniform. Stress-corrosion cracking was apparent in some welded joints which had been partially immersed: under similar conditions brazed joints were unaffected apart from undercutting of the base plate. The severity of the attack under partially-immersed conditions can be reduced by using annealed material and by stress-relief treatments.

'*Copper-Nickel Alloy:* Under conditions of total immersion its behaviour was similar to that of Monel. In partial-immersion tests attack was severe: the mechanism was not an intergranular one, but was rather a concentration-cell effect. Weld metal was more rapidly attacked than base-plate material: freedom from internal stress seemed to be desirable. In both Monel and copper-nickel alloy the copper was preferentially attacked.

'*Brazing Alloys:* The majority suffered a preferential solution of cadmium, zinc, tin, copper, etc., and were slightly embrittled: the silver-rich compositions are considerably superior as regards resistance to attack, in both partial- and complete-immersion tests.

* Polytetrafluoroethylene.

Nickel-containing Materials in Contact with Agricultural Chemicals

'Corrosion by Agricultural Chemicals.' *Corrosion Technology*, 1954, vol. 1, Oct., p. 295.

This is an extended abstract of a report from the Texas Engineering Experiment Station, U.S.A.

In connection with the spraying of crops from aircraft, selected structural materials (metallic and non-metallic) were exposed to the action of twenty-eight agricultural chemicals (representative of commonly used insecticides, herbicides, fungicides, defoliants, and fertilizers). Details are given of the individual types of chemical used.

In some of the tests the materials were partially submerged in the test media: in other cases the tests were under atmospheric conditions. Experimental procedure is described, in relation to conditions which would obtain during treatment of crops from aircraft. In both series the total duration of test was 79 days.

In the partially submerged tests 18-8 chromium-nickel steel showed complete resistance to corrosion throughout the test period. In the atmospheric tests it also gave excellent resistance to all the corrosives with the exception of the insecticide Toxaphene and sulphur-dust preparations, which caused slight pitting after 60 days' test. Monel gave excellent resistance in the partially submerged tests, with the exception of those made in highly concentrated potassium-cyanate solution, which caused slight pitting. Although in several cases Monel became discoloured, no major destruction was observed.

In the atmospheric tests the attack on this alloy was more severe: pitting began after 50 days on all specimens in contact with D.D.T. dust, Toxaphene-sulphur dust, potassium cyanates, and arsenate-dust insecticides. Brass, aluminium alloy, and chromium-molybdenum steel were all too badly attacked by certain of the chemicals to be considered for the purpose. Polyester plastic reinforced with fibreglass, which was among the non-metallic materials and finishes tested, gave excellent resistance to attack under all conditions.

Stainless Steel in Bone Surgery

F. P. BOWDEN and J. B. P. WILLIAMSON: 'Significance of Metallic Transfer in Orthopaedic Surgery.' *Nature*, 1954, vol. 174, Oct. 30, pp. 834-5.

Further to earlier correspondence (*ibid.*, vol. 173, pp. 520-2; *Nickel Bulletin*, 1954, vol. 27, No. 5, p. 96), the writers report additional experiments which confirm that in fixing of austenitic stainless-steel surgical-repair parts there is metal transfer from the tool to the screw or plate. The amount of transfer is dependent on the relative hardness and the specific nature of the contacting surfaces, but although a hard tool will lessen metal transfer it will cause increased mechanical deformation of the oxide layer on the screw and may thus affect the inertness of the metal.

Further work would be necessary to determine the relative importance of these factors. The experiments now reported serve to emphasize that some attention should be paid to the tools used in orthopaedic surgery, as well as to the buried metal.

Stainless Steel in Architecture

'Steel Wire Walls for Parking Garage.' *Steel*, 1954, vol. 135, Oct. 25, p. 93.

A photograph is shown of a new 12-storey parking garage under construction in Chicago. Curtains of stainless-steel wire strand, on 8-in. centres, are the only outside walls.

The 568 strands of wire are suspended at roof top, pass through tubular sleeves in each floor, and are secured at the bottom by turnbuckles and springs at 1,000 lb. tension. It is estimated that a saving of 65,000 dollars over (£23,000) will be effected by using the steel strand.

Corrigendum

Nickel Bulletin, 1954, vol. 27, No. 10, p. 212.

Para. 5. The carbon content given in brackets should read '0·51 per cent.' *not* '0·15 per cent.'

Binders bearing the date 195- and suitable for 1954 and 1955 Nickel Bulletins are now available. We shall be pleased to send one free of charge.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

SUBJECT INDEX TO VOLUME 27

The Index comprises a consolidated list of titles of abstracts compiled from the sectional contents lists of the individual issues.

Within the Sections normally used (**GENERAL, NICKEL, ELECTRODEPOSITION, etc.**), the items are broadly classified in appropriate sub-sections, within which the items are, in most cases, entered in the order of their appearance in the Bulletin. The only exceptions to such order are (1) the grouping of the page numbers of serial items, and of items of very closely related subject and, (2) the alphabetical order used in the 'General' Section.

Leading articles are listed separately, but are also shown in the appropriate sections, in which they are differentiated from abstracts by an asterisk at the beginning of the entry.

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THE MOND NICKEL COMPANY LIMITED
SUNDERLAND HOUSE · CURZON STREET · LONDON, W.1

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WESTMINSTER, LONDON, S.W.1